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AUTHOR McDermott, Hugh, Ed.; Scharmann, Larry, Ed.
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ABSTRACT

This 2-3 week high school chemistry unit is designed to provide students with an awareness of Gasohol as an energy alternative. Gasohol is a blend of 10 percent pure ethanol and 90 percent unleaded gasoline. The unit consists of nine activities (five laboratory experiments, three informational readings, and a sample problem activity). The five experiments cover fermentation, distillation, heat of combustion, and production of ethanol from corn. The three informational readings familiarize students with the concepts and vocabulary of Gasohol and other related terms. The sample problem worksheets (focusing on chemical reactions/calculations) can be assigned according to teacher judgment of what his or her class is capable of completing. Rationale, objectives, and instructional strategies are provided for the experiments, readings, and problems. Since a permit is needed for the production of ethanol, sample instructions for obtaining a permit and a sample permit are also provided. A list of process skills fostered, advanced teacher preparation, goals, planning guide, and evaluation suggestions are included in the introduction. (Author/JN)

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GASOHOL: AN ENERGY ALTERNATIVE

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Revised and Edited by Hugh McDermott Larry Scharmann

A Basic Teaching Unit on Energy

Gasohol: An Energy Alternative



Revised and Edited by

Hugh McDermott

Larry Scharmann

Recommended Subject: Senior High Chemistry

Original Writers
Ronald G. Crampton
Dan Haase
Edward Kinzer
R. Stephen Skinner

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The original "Basic Teaching Units on Energy" consisted of a package of 30 instructional packets contained within three volumes. The original fourteen units were written at the University of Nebraska-Lincoln, under the auspices of the Nebraska Energy Office, by Nebraska teachers participating in a three-week Faculty Development Institute sponsored by the U.S. Department of Energy (summer, 1978). The units were edited by the following individuals:

- Dr. Donald McCurdy, Professor of Science Education, University of Nebraska-Lincoln;
- Mr. Gary A. Lay, Education Coordinator, Nebraska Energy Office; and
- Dr. Robert Reeder, Science Department Chairman, East High School, Lincoln, Nebraska.

An additional eight units were written by independent authors in the summer of 1979 and the final eight units were developed as a result of a second federal grant (summer, 1980).

The present format has been achieved as a result of an evaluation conducted by the Nebraska Energy Office, February, 1981. Rather than continue to offer all 30 units as a single package, the Nebraska Energy Office determined to revise, edit, and typeset the 10-12 highest quality units and continue to offer the other units in their present format.

The editors of these revised "Basic Teaching Units" wish to thank the individual writers, original editors, and clerical staff for their contributions in creating the "Basic Teaching Units".

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TO THE INSTRUCTOR . . .

"Gasohol: An Energy Alternative" is a chemistry unit designed to provide students with an awareness of Gasohol as an energy alternative. Gasohol is a blend of 10 percent pure ethanol and 90 percent unleaded gasoline.

The unit consists of nine activities, five of which are actual classroom experiments, three informational readings, and a sample problem activity. The five classroom experiments cover fermentation, distillation, heat of combustion, and the production of ethanol from corn. The three informational readings will familiarize students with the concepts and vocabulary of Gasohol and other related terms. The sample problem worksheets can be done according to teacher judgment of what his or her particular class is capable of completing.

The materials for most experiments can be found in most chemistry classrooms. **It should be noted that a permit** is needed for the production of ethanol. This can be obtained rather easily but needs to be obtained prior to producing alcohol.

Finally, since material sources continue to change periodically, the source, **Energy Info Publications, Audio-Visual Materials**, contains a list of general topics and materials available from the Nebraska Energy Office. You are encouraged to use the ordering page attached to this unit to obtain this booklet as well as other energy related materials.

Larry Scharmann
Education Coordinator
Nebraska Energy Office
P.O. Box 95085
Lincoln, NE 68509
(402) 471-2867

Gasohol: An Energy Alternative

Abstract

This unit consists of nine separate activities. It can be approached several different ways. It is suggested that the first three activities be used as informational activities which will give students some background information concerning Gasohol. All or some of the remaining six activities can be done in any order. There are two experiments on fermentation, one on the distillation of the liquid from grain fermentation, a heat of combustion of ethyl alcohol experiment, and a laboratory experiment in which ethanol is produced from corn. The sample problems allow students to calculate and solve experiment-related problems.

Recommended Level

Grades 10-12

Academic Areas

Chemistry

Time Required

2-3 weeks

Process Skills

- | | |
|-----------------|--------------|
| —calculating | —identifying |
| —comparing | —measuring |
| —discussing | —observing |
| —experimenting | —reading |
| —gathering data | —recording |
| —hypothesizing | —writing |

Advanced Teacher Preparation

Obtain: Energy Films which may be applicable to a particular activity or unit. The following are available:

GASOHOL: "Gasohol Continues to Grow" Slide Show (12 minutes) Available from:
NEBRASKA GASOHOL COMMITTEE
3rd Floor — 301 Centennial Mall South
P.O. Box 94831
Lincoln, NE 68509-4831
(402) 471-2941

A list of equipment suppliers from which chemical and other necessary supplies may be purchased. This can be obtained from:
NEBRASKA GASOHOL COMMITTEE
P.O. Box 94831
Lincoln, NE 68509

Read: Energy Info—Publications, Audio Visual Materials available from the Nebraska Energy Office.

Goals

To get students to become aware of energy resources and alternatives.

To have students examine the biological and chemical principles which can be applied to the study of Gasohol.

To have students confirm hypotheses through experimentation.

Student Objectives

These are included previous to each activity.

Planning Guide

Day 1

Activity #1 "What About . . . Alcohol As A Fuel"

Day 2

Activity #2 "A Fact Sheet on Gasohol"

Day 3

Activity #3 "Alcohol Fuels Glossary"

Day 4-14

Teacher Choice

Evaluation Suggestions

Evaluation of this unit depends on how each activity is used and is therefore up to the individual teacher. As a suggestion, however, each student could be given the following questions as a pre-test and post-test. The sample problems may also be used as part of the evaluation.

- 1) What is gasohol?
- 2) How is ethanol produced? What processes are used?
- 3) What are the advantages and disadvantages of making ethanol from grain?

"What About . . . Alcohol As A Fuel"

Rationale:

Many people believe that if grain is used for the production of ethanol, that this will take away a valuable and needed food supply. This reading contains basic factual information concerning ethanol as well as some advantages and disadvantages in the production of this fuel.

Objectives:

Students will be able to read the article, "What About . . . Alcohol As A Fuel."

Students will be able to identify some advantages and disadvantages in the production of ethanol.

Implementation:

Hand out the article for reading. Have students discuss this after they read it.

Debriefing:

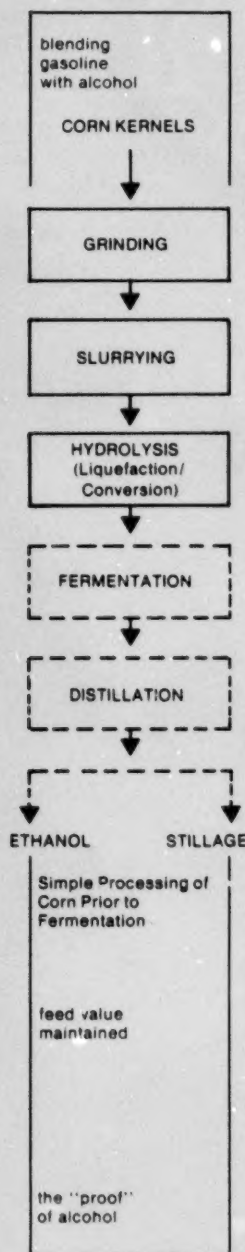
It may be necessary to explain the graph which follows the reading. The transparencies illustrating the advantages and disadvantages may prove useful.

Gasohol An Energy Alternative

Activity #1

Name _____

Date _____



Grain alcohol is a fuel, either straight or blended with gasoline.

Blended with gasoline, corn alcohol offers a high performance automotive fuel. The blend of 10% alcohol with 90% gasoline, under the designation "Gasohol," is in wide public use in Iowa and growing nationally. Research done in Brazil indicates that as much as 20% alcohol can be used in gasoline blends without requiring engine or carburetion adjustment. However, when blending alcohol and gasoline, something very close to a 200-proof alcohol should be used to protect the fuel from phase separating.

Consumer research shows that motorists believe Gasohol to be a superior fuel to "straight gasoline," that they are willing to pay a premium for the higher octane Gasohol blend, and that their cars perform well. Many claim that Gasohol increases their mileage.

Some pioneering farmers have shown that corn alcohol in the 165-180 proof range can be used as a complete fuel replacing gasoline.

While alcohol will not blend with diesel fuel, one ingenious farmer has modified a diesel tractor to burn diesel and grain alcohol (on a 50-50 basis) by installing a carburetor and adding a separate alcohol fuel tank. The mixture is thus actually made in the ignition chamber.

In Brazil, the world leader in development of this replaceable fuel, alcohol is being tested to totally replace petroleum fuel in diesel engines. Brazilians have shown a blend of 80% alcohol with 20% vegetable oil works efficiently in diesel trucks and tractors.

While alcohol provides somewhat less actual combustion energy than gasoline, its burning quality is such that it permits a leaner fuel-air "mix" . . . compensating for the slightly lower combustion factor.

Used as a complete fuel, ethanol can carry up to 20% water, and this lower-proof alcohol is considerably less expensive to manufacture.

Grain alcohol is a fuel.

General Background, Language

Alcohol produced from grain is called ethanol. Alcohol from petroleum and wood materials is methanol.

A bushel of corn can produce about 2.6 gallons of alcohol and 17-18 pounds of high-protein feed.

"Proof" describes the portion of alcohol in the final fluid. The proof figure is double the percentage, vis: 180 proof equals 90% alcohol, 160 proof equals 80% alcohol. The remainder is water.

Alcohol is derived from the starches (sugars) in the grain, via a process of fermentation.

The second major step in alcohol production involves vaporizing, to drive the alcohol out of the alcohol-water solution, and allowing it to condense in a less diluted form. This is the distillation step . . . from which the slang word "still" is derived.

Proteins in the corn remain after alcohol is removed, which means the corn's original feed value is preserved. Commercial distilleries dry this grain residue, and call it DDG . . . distiller's dark (dried) grain. (Farmers can save the extra cost of drying and use or sell the residue as a wet feed.)

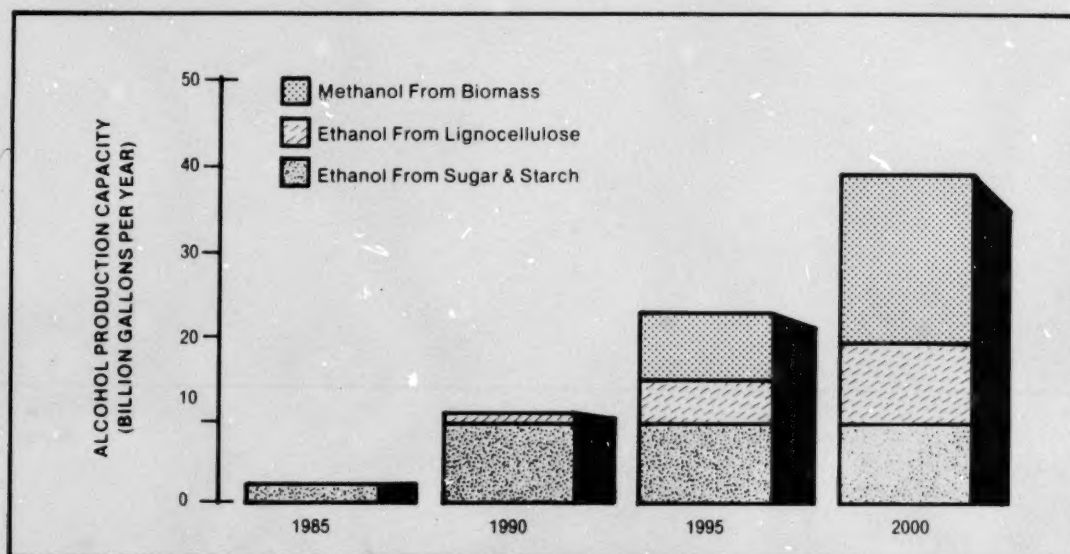
Fuel alcohol is being used in two ways: At a high-proof level (196-200), it can be mixed with gasoline and burned as Gasohol. When alcohol proof is lower, it may be used as a complete fuel in cars, trucks and tractors.

Water at high levels in alcohol will not blend with gasoline . . . and settles out. However, the lower-proof alcohol burns hot enough to perform well in engines despite the water content. You will need to have at best 160 proof out of the still to meet federal denaturing regulations.

ADVANTAGES

- + Corn alcohol is a good fuel, in a Gasohol blend or as a complete engine fuel.
- + On-farm production of ethanol would give you an **assured** supply of fuel for your farming needs . . . for tractors, trucks, cars, home heating, livestock facilities, etc. Current short supplies of gasoline and diesel fuels (June, 1979) have made assured supplies a high priority item.
- + Conversion of corn for use as fuel would eat into surpluses and give a helpful boost to crop prices.
- + On-farm plant can be operated off-season, when time is available to operate the still.
- + Since virtually all of corn's high-protein feed value remains after the alcohol is removed, the "distiller's grains" can go right back into livestock feed . . . or be sold to a neighbor. You can make fuel and still have most of corn's feed value left. (By feeding the supplement at home or close to the farm, you'll also avoid the costly step of drying down the stillage).
- + You may find it possible to use farm wastes to "power" the still. Burn stalks, cobs, waste from timber, sawdust from a nearby mill . . . anything that will burn in a boiler. Collect and use methane from livestock manure . . . or go to a solar collector.
- + You may be able, with careful planning, to "re-use" the heat from the still to warm the home, the confinement facility . . . and reduce electrical or other family fuel costs.
- + You may be able to reduce the cost of truck and tractor fuel, because you can probably make alcohol on-farm at less cost than buying petroleum derived fuels. Savings can come from:
 - A. Using wet corn, which means you can eliminate the cost of drying grain after harvest.
 - B. Because **raw material** is home-grown, you'll avoid costs of shipping the grain to a distillery. No transportation on the fuel end, either. You can pump from the alcohol storage tank to the tractors.
 - C. Your high-protein residue costs less than commercial DDG, because you need not dry it down before feeding.
 - D. Using damaged, cracked, moldy and other off-grade corn, which carries the usual protein and alcohol content, but has little cash value if not used for fuel.
 - E. Using your own labor, ingenuity, plumbing and welding skills in the construction of the fuel-alcohol plant.

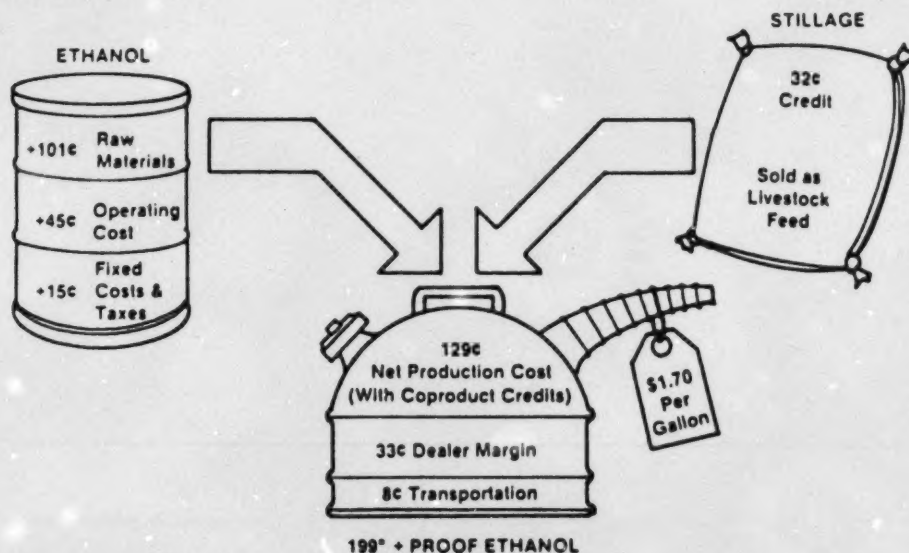
There are a lot of plus factors above, not to mention personal satisfaction. But like most "deals," there are some negatives to be mulled over before you invest in steam boiler, vats and distilling columns.



DISADVANTAGES

- You'd be breaking new ground, with few trails to follow. As yet, despite a lot of talk, there are virtually no on-farm plants actually built and operating. Many could be operational a year from now, but at this moment, you have little success to copy and therefore little failure to study and avoid.
- While there are plant designs and systems being offered from several sources, we haven't found (as of June, 1979) a single "packaged" unit installed on-farm, tested out, and operating.
- Cost estimates, for either turnkey stills or plans-plus-components, are not yet locked in. There seems to be little agreement, even on the fairly basic factors: the kind of metal for distillation columns; the kind and extent of automation which will help a small-unit operator avoid trouble.
- You won't learn still operation overnight. The process of converting corn to alcohol is fairly complicated, even for a do-everything-yourself farmer. You'll need some chemistry, some steam engineering, some microbiology, some plumbing, plus some housekeeping.
- Engine modifications may be necessary before straight farm alcohol or alcohol in combinations with gasoline or diesel can be used in tractors, trucks, and/or cars.
- None of the major tractor companies (to our knowledge) have published test results on engine wear using alcohol or a combination of alcohol and petroleum-based fuels.
- Although efforts are underway to streamline the procedure for obtaining permits, licenses and clearances, the paperwork is still a demanding task.
- Looking longer range, you'll have considerable investment in your fuel plant. If corn should go to \$3.50 or \$4.00 in a couple of years, you may find yourself priced out of the corn-alcohol business. You would then need to find an alternate supply of raw materials to keep your still going. Could you live with an idle plant? Or would you figure the plant a good investment if it helped get corn prices back up to profitable levels?
- Because lending agencies, private and public, have no prior "track record" on small distilleries credit may be difficult.

The decision is yours to make.



199° + PROOF ETHANOL

SOURCE U.S. DOE 1st Annual Report to Congress (Revised)

Figure I-7. Breakout of Production Costs for Ethanol

Gasohol: An Energy Alternative

Conversion Process . . . Corn to Alcohol

Page 1

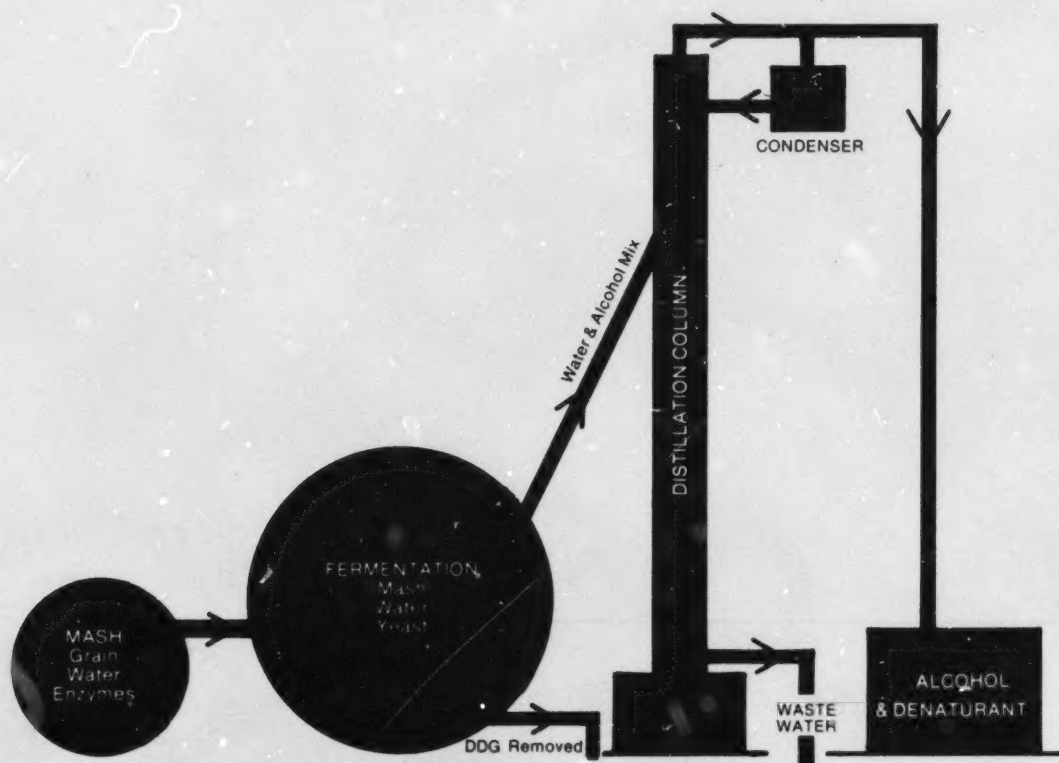
Name _____

Date _____

The basic technology for obtaining alcohol from plant life goes back thousands of years.

With some modern improvements, the process has become more efficient. The following is a simplified set of steps for use in small alcohol plants.

1. Grind or mill the kernels into fairly uniform "fine" sizes. (A 3/16th hammermill screen will do the job).
2. Make a slurry (mash) by adding about 16 gallons of water per bushel of corn.
3. Adjust the pH level of the mash to a 6.0-7.0 range, using acids and alkalis to reach the balance needed.
4. Add an enzyme, Alpha Amylase, and cook the mash at a boil for 30 minutes, with constant agitation. This step converts the starches to gelatin.
5. Cool the slurry to 85-90 degrees, thin and mash by adding 16-18 gallons of water per bushel (which also helps the cooling).
6. Adjust the pH level down to a 4.0-4.5 range, add a second enzyme, Gluco-Amylase, and inoculate with a yeast culture (brewer's yeast) on a basis of 2-4 oz. per bushel of corn.
7. Allow to ferment for 60-70 hours at 85-90 degrees, with agitation. This step produces ethanol (grain alcohol) from the fermentable sugars.
8. Screen out the distiller's grain, leaving the "beer" (alcohol and water) for the final step. . .
9. The beer is run through an upright distillation column at near-boiling temperatures. Since alcohol vaporizes at 173 degrees, the vapor rises and leaves the column, goes into a cooling tank where it becomes liquid. (Low-proof alcohol should be run through the distillation column a second time to reduce its water content).
10. Denature the alcohol (under federal direction), and feed the DDG as a high-protein supplement.



"A Fact Sheet on Gasohol"

- Rationale:** Practical application is useful and possible with ethanol. This reading explains more about ethanol and its uses in actuality. It explains biomass and how Brazil makes practical use of gasohol from grain.
- Objectives:** Students will be able to read the article.
Students will be able to identify and explain how ethanol can be made useful.
- Implementation:** Hand out the reading "A Fact Sheet On Gasohol." Students should read this article and be able to identify ways ethanol is used presently.
- Debriefing:** After reading and discussing this article, it may be necessary to explain and discuss the grain alcohol plant flow diagram.

Gasohol: An Energy Alternative

A Fact Sheet on Gasohol

Activity #2, Page 1

Name _____

Date _____

Solar energy is often mentioned as a promising alternative to our energy problems. The problem, of course, is finding some convenient way to store this solar energy. Whether as a nation we realize it or not, the coal and oil we consume in such massive quantities is simply stored sunlight. The "storage" of this sunlight took place many millions of years ago when ancient sunlight, carbon dioxide and water were absorbed by equally ancient green plants to make what we would now call fossil plants. These plants decayed to produce, over millions of years, coal and oil-stored vintage sunlight.

It seems inviting to think that it ought to be easy to urge our leafy brethren to simply make more coal and oil. Unfortunately, it simply is not that easy. No one has discovered how to make chemical and physical reactions happen overnight which really took millions of years to happen naturally. In spite of this, our chlorophyll-containing friends do hold the promise of a solution to our supply of fossil fuels, which must certainly be finite in quantity.

The way in which green plants can provide us with energy does not involve new, unheard of technology, but may involve a word new to you—biomass. Simply stated, biomass refers to nature; harvested plants which have converted sunlight, carbon dioxide and water into organic carbon compounds. These plants may be burned as is (e.g. wood) to produce energy or new chemicals may be made from the plants. These "new" chemicals can then be burned as fuels.¹

One of these "new" chemicals which can be obtained from plants is really old—almost older than man's recorded history. Egyptian and Mesopotamian artifacts show pictures of men fermenting grain to make alcoholic beverages at least 2500 B.C.

Besides its use as a beverage, alcohols can be used as fuels, and this is the energy promise which plants hold for us.² Let plants convert sunlight, carbon dioxide and water into plant sugars, ferment the sugars to make alcohol, and burn the alcohol as a fuel. The benefit, of course, is that the plants grow yearly to replenish the burned up alcohol supply.

Could this scheme to replace our coal and gasoline burning devices with alcohol burners ever really work? Not only could it, it has! During World War I and II when gasoline was in short supply in Germany and France, many military tanks and planes carried "wood stills" on the vehicle, which heated or "distilled" wood. One of the products of distilling wood is an alcohol called "methanol" or "wood alcohol," which was then burned to power the tanks and planes. In 1938 some 9,000 of these wood burning alcohol makers were being driven in Europe. Even in the U.S., as early as 1920, methanol was produced as a fuel for airplanes. As of 1972, 1 billion gallons of methanol were produced, but virtually none were used as a fuel. In 1972 methanol was used as a solvent—paint thinner and in the production of plastics. The reason alcohols aren't used as fuels today is simple to understand. Both methanol and ethanol are made from petroleum today, because petroleum is the cheapest way to make these alcohols. This may not always be the case.

Brazil is a good case in point. In 1977 Brazil was forced to import 80 percent of its oil, as opposed to 50 percent for the U.S. In Brazil the 1977 price of gasoline was \$1.50 per gallon. The total cost to Brazil for its fuel in 1977 was 3 billion dollars. Brazil simply can't afford this. As a result, Brazil has committed \$400 million since November of 1975 to gradually increasing ethyl alcohol production. The plan is to mix ethanol with gasoline so that by 1980 "gasoline" would be 20% ethanol and 80% gasoline in Brazil. The advantages to Brazil are obvious, but where will the ethanol come from? Plants to the rescue! In Brazil the plan is to grow sugar cane or a starchy root plant called manioc. The sugar from the sugar cane and the starch from the manioc can both be fermented to make ethanol. Brazil is going to build alcohol plants to make their fuel.³

Will this alcohol-gasoline mixture really burn as well as gasoline, or is it just a desperate substitute? In Nebraska, starting in 1974, 45 vehicles were run for almost 3 years on gasoline-ethanol mixtures which were 10 percent ethanol and 90 percent unleaded gas. Altogether, two million miles were covered in this experiment. The 10 percent to 90 percent mixture was and still is called gasohol. During this time, odometer readings and gallons of gasohol added

introduction

stored
sunlight

fossil fuels
take time
to produce

biomass
energy

fermenting
grains

alcohol as a
beverage and
fuel

using alcohol in other
burning devices



burning alcohol

¹ Gasohol can be burned in any internal combustion engine regardless of age without carburetor modification.

² Gasohol has an octane rating 3 points higher than unleaded gasoline.

³ Gasohol causes no unusual engine wear.

Ethanol can be used for a fuel as

• various ethanol-gasoline blends,

• hydrated (lower proof) ethanol,

• straight anhydrous ethanol, and

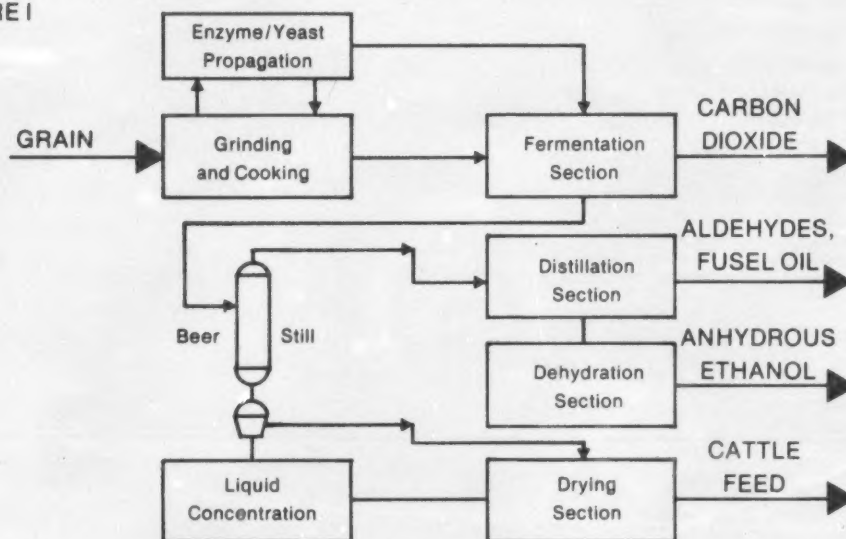
• dual-carbureted diesel fuel supplement.

were recorded at each refueling.⁴ Spark plugs were examined and compression measurements made periodically. The engine heads were removed from 10 vehicles, the valves and valve seats examined, and the cylinder diameters measured for wear. In addition, exhaust emissions were tested on some of the vehicles.⁵

It all sounds too good to be true doesn't it? A renewable fuel component which operates as well or better than pure gasoline. Why don't we make it? Well, we can and we have in the U.S. For us, a logical choice would be to ferment grains such as corn, wheat or milo, which we grow in Nebraska and other midwestern states in surplus quantity. How would such a plant operate? A flow chart of a typical ethanol plant is shown. (Figure 1)

If you take a moment to look at it, you will discover a true serendipity. Besides the alcohol, fermentation of grain produces other saleable products including carbon dioxide to make dry ice or put the fizz in pop, and something called D.D.G.—distillers dried grain—which is the dry product left over after all the liquids from the fermentation are boiled off. This DDG is an excellent protein source and has been used as cattle feed with good results. Experiments to convert the DDG to a palatable human protein food are also being done. In a world with many mouths to feed, it "goes against the grain" of some people to use food to make fuel. For-

FIGURE 1



GRAIN ALCOHOL PLANT FLOW DIAGRAM

unately, the fermentation of grains is able to provide both. The carbohydrate of the grain is converted to alcohol for use and the protein of the grain is concentrated, then dried into a solid protein food source.

Is it really possible to grow our fuel and eat it too? Right now the best answer seems to be a definite **maybe**. Dr. William Scheller, (University of Nebraska-Lincoln) one of gasohol's leading advocates, sums it up nicely. "At least three factors are important to the economic future of gasohol. They are: the price of gasoline, the price of grain, and the value of DDG from the ethanol manufacturing process . . ." Scheller feels that the economics for gasohol production are favorable now. Other equally informed people feel that gasohol cannot be made today on a large scale and compete with gasoline. Whether or not we ever produce gasohol on a large scale will undoubtedly depend on whether our energy situation becomes more like Brazil's present condition.

⁴ Gasohol fueled vehicles consumed 5% less fuel than vehicles driven only on unleaded fuel.

⁵ Exhaust emissions from gasohol contained one-third less carbon monoxide and one-tenth as many hydrocarbons as the emissions from unleaded gasoline.

maybe it's feasible

producing gasohol depends on three factors

"Alcohol Fuels Glossary"

- Rationale:** In discussing gasohol, there are certain terms or words which explain this topic. The glossary will provide definitions of these terms and the crossword allows students to become familiar with some of them.
- Objectives:** Students will be able to review glossary terms.
Students will be able to complete the crossword puzzle and use some of the glossary terms.
- Implementation:** Hand out the "Alcohol Fuels Glossary" and review the terms with students. Have students complete the crossword activity (Optional).
- Debriefing:** The crossword activity is optional depending on what the instructor feels is appropriate for his or her class.

Gasohol: An Energy Alternative

Alcohol Fuels Glossary

Activity #3, Page 1

Name _____

Date _____

alcohol	a class of chemicals (composed of carbon, hydrogen, and oxygen) which can be burned as a fuel. Ethanol and methanol are the two main types being considered for fuel use. Compare gasohol.		
anhydrous	containing virtually no water. Anhydrous alcohol (200 proof) can be mixed with gasoline without risk of separation.		
biomass	any plant material that may be used to produce food, feed, fiber, or energy, including grains, cornstalks and other agricultural residues, fruits and vegetables and their processing byproducts, and bagasse (residue from processing sugar cane); wood products and residues from logging and paper manufacturing; and aquatic plants. The term is often used to include animal manure.		
Btu	a unit of measurement that provides a way to compare the energy available in different fuels or other energy sources. One Btu is the amount of heat energy it takes to raise the temperature of one pound of water one degree Fahrenheit. (Note: Though ethanol averages 84,000 Btu/gal., about 2/3 of the Btu in gasoline, it has combustion properties that enable it to achieve better mileage/Btu than gasoline).		
cellulosic material	crop stalks, forest residues, and portions of urban waste that can be processed into alcohol fuels once treated with acids or enzymes to break them down into fermentable sugars. Use of these materials to make alcohol fuels on a large scale depends on improving the efficiency (now 20%) of this hydrolysis, or breaking down, step.		
conversion ratios	1 bushel of corn = 2.73 gal. of 190 proof or 2.55 gal. of 200 proof ethanol 1 ton of crop residue = 0.8 tons of fermentable sugar = 121.21 gal. of 200 proof ethanol 1 barrel = 42 gallons		
denaturant	a substance added to ethanol to make it unfit for human consumption so that it is not subject to alcohol beverage taxes.		
destructive distillation	a process to produce fuel from cellulosic materials by heating them in the absence of oxygen, decomposing the material, and then distilling the resulting vapors. Compare hydrolysis.		
distillation	the last stage in making alcohol from fermentable sugars. The "beer" (fermented feedstock containing about 85% water) is heated in a distillation column, or still, to boil off the water and the alcohol, which is condensed and piped off to a storage tank. In "vacuum" distillation, the process takes place at lower pressure, which makes it possible to distill the alcohol using less heat energy.		

distillers' mash	a protein- and mineral-rich byproduct of alcohol production from grain. When water has been removed, this byproduct is called distillers' dried grains, or DDG, and can be stored and transported without spoilage. Distillers' mash and DDG are currently used as animal feed supplements (they have higher protein value—22-27%—than the original grain itself), and research is underway on using DDG as a human food supplement.
ethanol (ethyl or "grain" alcohol)	an alcohol made from grains as well as from starch-and sugar-rich crops by fermentation and distillation; from cellulosic material (which must undergo hydrolysis first); or from petroleum products like ethylene (by reacting to them with a catalyst). Ethanol can be blended with gasoline as an extender and octane booster. Ethanol contains 2/3 of the energy in Btus of an equal volume of gasoline but can provide more miles per Btu.
excise tax, gasoline	a tax collected at the pump to support the construction and maintenance of highways. Gasohol is exempt until 1984 from the \$.04 federal excise tax and in some states from the state excise tax.
feedstock	the raw material from which alcohol can be made, including distressed or sub-standard grain, grain sorghum, sugar beets, sugar cane, potatoes, fruits, vegetables, cheese whey, food wastes, and potentially cellulosic materials and municipal solid waste.
fermentation	a step in the production of ethanol from agricultural products. Bacteria or yeast added to a "mash" of grain, sugar beets, or other agricultural product, break down the sugars into alcohols. The resulting "beer" must then be distilled to produce alcohol of a "proof" suitable for fuel use.
gasohol	a mixture of 10% 200-proof ethanol and 90% unleaded gasoline.
hydrolysis	the first step in producing ethanol from cellulosic materials (like wood, urban waste, and vegetable residue). Hydrolysis uses enzymes and/or acid to break down cellulose into sugar before fermentation and distillation can take place. Compare to destructive distillation.
methanol (methyl or "wood" alcohol)	an alcohol made from wood or carbonaceous urban waste (by reacting that gas with a catalyst), or from coal (by liquefaction—a technology that is being advanced for commercial use in this country). Methanol can also be used as a gasoline extender and octane enhancer but, since it tends to corrode certain seals and metals, is likely to come into wider use only when materials and engines are modified to accommodate it.
net energy balance	the amount of energy available from a fuel when it is burned minus the amount of energy it takes to produce the fuel.
proof	the volume of ethanol in a liquid is proof. Proof is twice the percentage number, so a liquid that was 100% ethanol would be 200 proof. The higher the proof, the more Btus are available when the liquid is burned.
still	the apparatus used to distill alcohol, that is, to remove water from it in successive stages in order to increase its proof.

Across

1. the last stage in making alcohol from fermentable sugars
3. a mixture of 10% ethanol and 90% unleaded gasoline
5. a measure of ethanol content, 1 percent equals 2 _____
8. apparatus used in making alcohol
11. the step in the ethanol process where bacteria or yeast is added
12. ethanol and methanol are the two main types of this fuel.

Down

1. a substance added to ethanol
2. containing virtually no water
3. corn, wheat, and barley are known as _____ products
4. abbreviation for British Thermal Unit
6. an alcohol made from wood
7. plant or animal material used to produce food, feed, fiber or energy
9. a mixture of grain and other ingredients with water to prepare wort for brewing operations
10. another name for methanol alcohol is "_____ alcohol"
11. a material used to produce heat or power by burning.

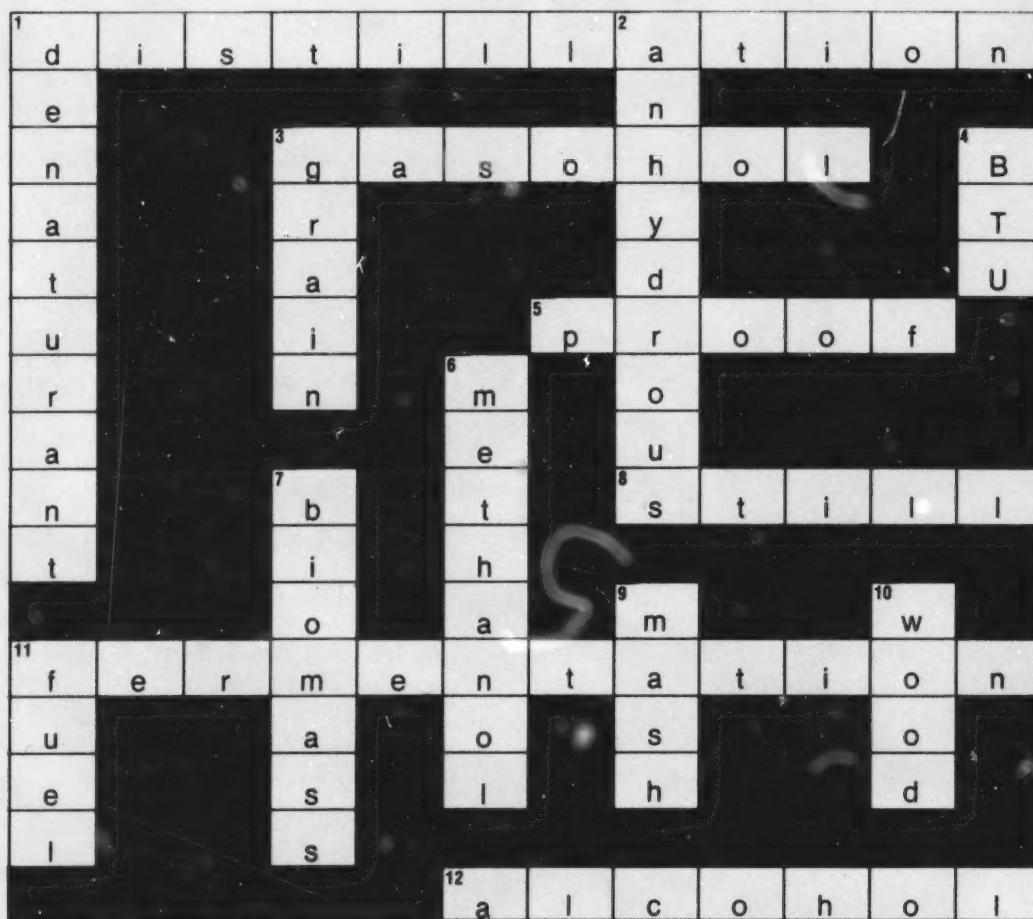


Across

1. the last stage in making alcohol from fermentable sugars
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Down

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9. a mixture of grain and other ingredients with water to prepare wort for brewing operations
10. another name for methanol alcohol is " _ _ _ _ " alcohol
11. a material used to produce heat or power by burning.



Fermentation of Grain for Ethanol Recovery

Concept

Ethanol produced by fermentation.

Question

How is ethanol produced from grain?

Objectives

Students will be able to observe the experiment taking place.

Students will be able to hypothesize how ethanol is formed. Students will be able to identify the chemicals involved in the transformation.

Process Skills

hypothesizing, identifying, measuring, observing, recording

Time

3-4 days for germination and 1 day for the experiment

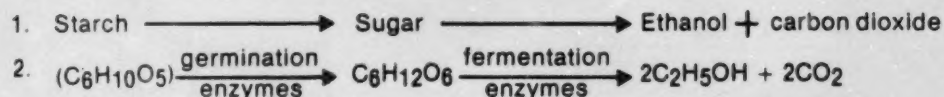
Background

Relying on one of nature's oldest known chemical reactions, fermentation, ethanol can be produced from replenishable grain sources rather than limited petroleum reserves. Ethanol produced from fermentation of grains might be used in the suggested gasohol program.

Before grain can be fermented it is first necessary to convert grain starch into sugar. This is done by germinating the seeds. During germination, enzymes found beneath the seed coat, convert the stored starch into sugar.

Having obtained a supply of sugar the fermentation process can begin. Yeast is added to the mixture. The yeast converts the sugar present into alcohol. When the alcohol content reaches 15%, the yeasts are killed, thus ending the production of alcohol.

In fermentation the following reaction occurs:



This lab is designed to show that grain can be used to demonstrate fermentation.

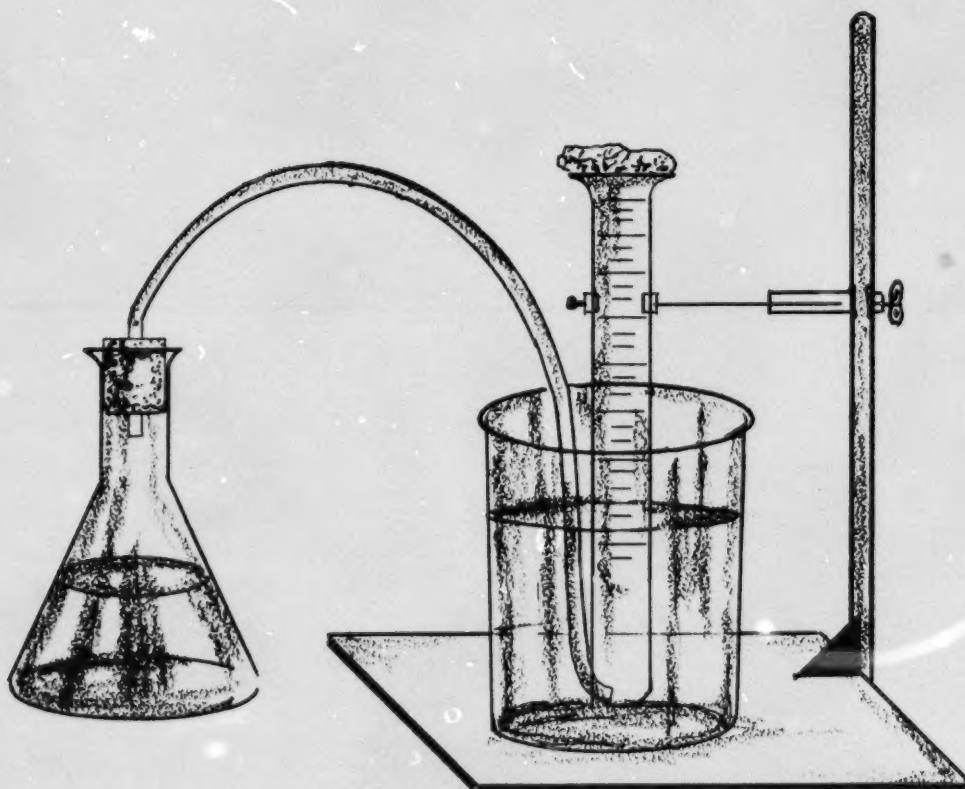
Materials:

- (1) 500 ml flask
- (1) rubber stopper (1 Hole)
- glass tubing
- (1) ring stand
- (1) test tube clamp
- (1) rubber hose
- (1) 100 ml graduated cylinder
- (1) 500 ml beaker
- 400 ml distilled water
- 100 g grain (corn or milo)
- 1 g sodium hydrogen phosphate (Na_2HPO_4) Lime water
- 1/4 package dry yeast

Procedure/Sequence

Note: There have been a number of problems reported using this procedure. The teacher should plan to research and modify the procedure as needed.

1. Germination of Grain
 - a. This is done by adding 200 ml distilled water to the 100 g of grain in the 500 ml flask.
 - b. Place the culture in a warm (90-100°F) location for 3-4 days.
2. Fermentation of Grain
 - a. After germination has occurred add an additional 150 ml distilled water to the flask and bring this mixture to a boil for 15 minutes.
This heating is done to kill unwanted bacteria.
 - b. Let the mixture cool to less than 100°F. It is VERY IMPORTANT that the mixture is not warmer than this.
 - c. To the cooled mixture, add 1 g Na_2HPO_4
 - d. Dissolve $\frac{1}{4}$ package of yeast in 50 ml of warm water; add this mixture to the flask.
 - e. Place the rubber stopper in the flask and set up the apparatus (see diagram) to measure gas (CO_2) production.
 - f. Record the volume of gas present in the graduated cylinder every other day until there is no longer an increase in the gas volume or until volume becomes too great to measure.
 - g. Record the temperature of the room and barometric pressure on the final day of recording of gas volume.



(Fig. 1) — The graduated cylinder should be immersed as far as possible in the beaker containing lime water. The volume of air that remains should be recorded.

An Alternative Fermentation Procedure

Concept

Ethanol produced by fermentation.

Question

How can I tell that fermentation is taking place?

Objectives

Students will be able to observe the process of fermentation taking place.
Students will be able to perform the demonstration.

Process Skills

hypothesizing, identifying, measuring, observing, recording

Time

Actual experiment will take about 10 minutes, but total time needed is from 3-5 days.

Background

This experiment allows students to observe that some chemical is being given off when yeast is added to the corn syrup and water mixture.

Materials (per class of 30)

350 ml corn syrup
3 liters of distilled water
½ package dry yeast

1 gallon bottle
1 balloon

Instructor Information . . .

Procedure/Sequence

Mix the corn syrup and water in a gallon bottle.

Add dissolved yeast.

Place balloon on top of bottle and let sit for 3-5 days.

Observe expanding of balloon. When fermentation is no longer occurring, the balloon will decrease in size.



The Distillation of the Liquid From Grain Fermentation

Concepts

- Determining the percent composition of the fermentation liquid.
- Making a qualitative test for the presence of an alcohol.

Question

What percent of pure ethanol remains after distillation?

Objectives

- Students will be able to calculate the percent composition for the fermentation liquid.
- Students will be able to graph temperature vs. time for this experiment (optional).

Process Skills

Calculating, hypothesizing, identifying, measuring, observing, recording

Time

To be determined by the instructor.

Background

The boiling point of a pure liquid is an excellent characteristic property useful for isolating a component of a solution. This is no exception for the liquid produced by fermentation. The ethanol can be separated by distillation. This is complicated only by the fact that 100 percent absolute alcohol doesn't distill from a fermentation solution. An azeotrope forms, which distills at 78.2°C, instead of 78.5°C for 100 percent ethanol. Since the ethanol-water azeotrope remains constant in composition, no amount of distilling produces 100 percent pure ethanol, rather a 95 percent ethanol-5 percent water mix distills continuously at 78.2°C.

The purpose of this experiment is to determine the percent composition of the fermentation liquid and to make a qualitative test for the presence of an alcohol.

Materials for the distillation:

30-50 cc of filtered fermentation liquid. (The glassware for the distillation may be as sophisticated as bonafide distillation flasks with water jacket condensers or as simple as flat bottom flasks with stoppers and air cooled glass bends.)

Although bunsen burners are an adequate heat source, hot plates reduce the chance of alcohol fires.

Containers to receive fractions collected.

Student grade celsius thermometer with 1° increments.

Ring stand(s) and clamp(s) as needed.

Procedure

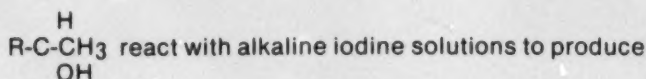
Heating should take place at a rate to produce 1 to 2 cc of distillate per minute. Care should be taken as heating to dryness approaches. Any solids dissolved in the fermentation liquid which are organic (e.g. sugar) may decompose if heated too strongly. This complicates clean-up. The teacher should instruct students at which temperatures to collect fractions.

The minimum data required to determine the percent composition of the fermentation liquid are:

- 1) The mass of the distillation flask and fermentation liquid,
- 2) The mass of the distillation flask,
- 3) The mass of each distillate receiver and distillate, and
- 4) The mass of each distillate receiver.

Test for Ethanol (R represents an alkyl radical)

Secondary Alcohols of the type



iodoform, CHI_3 , which is a yellow crystalline solid at room temperature. The procedure for the test and the reaction forming iodoform are given below:

Comparison of the fermentation distillate with pure ethanol is recommended. To 5 cc of distillate, add 2 cc of 10 percent sodium hydroxide solution. Next add, drop by drop, a solution of sodium iodine and iodine (Lugol's solution) to the distillate until a slight iodine color remains.

Warm the distillate to 50°C for 15 minutes, then cool. Yellow CHI_3 crystals should form. (These CHI_3 crystals explode at 210°C). Besides this chemical test, the boiling point and a density determination are also possible. The difference between the density of absolute ethanol and 95 percent ethanol is too close to measure reliability with centigram equipment.

**Safety**

Lugol's solution represents a hazard because of the iodine. It would be wise to have a sodium thiosulfate solution handy to convert any spilled I_2 to I^- .

Gasohol: An Energy Alternative

**The Distillation of the Liquid
From Grain Fermentation
Worksheet, Page 1**

Name _____

Date _____

Directions: Make the necessary calculations and answer the questions.

1. Calculate the percent composition for the fermentation liquid.

2. Natural fermentation can produce only about 15 percent ethanol solution. Why?

3. A typical 90 proof hard liquor is about 45 percent alcohol. How can such a beverage be made if natural fermentation can only produce a 15 percent alcohol solution?

4. If distillation of a fermented product can produce only 95 percent ethanol, how is 100 percent ethanol made?

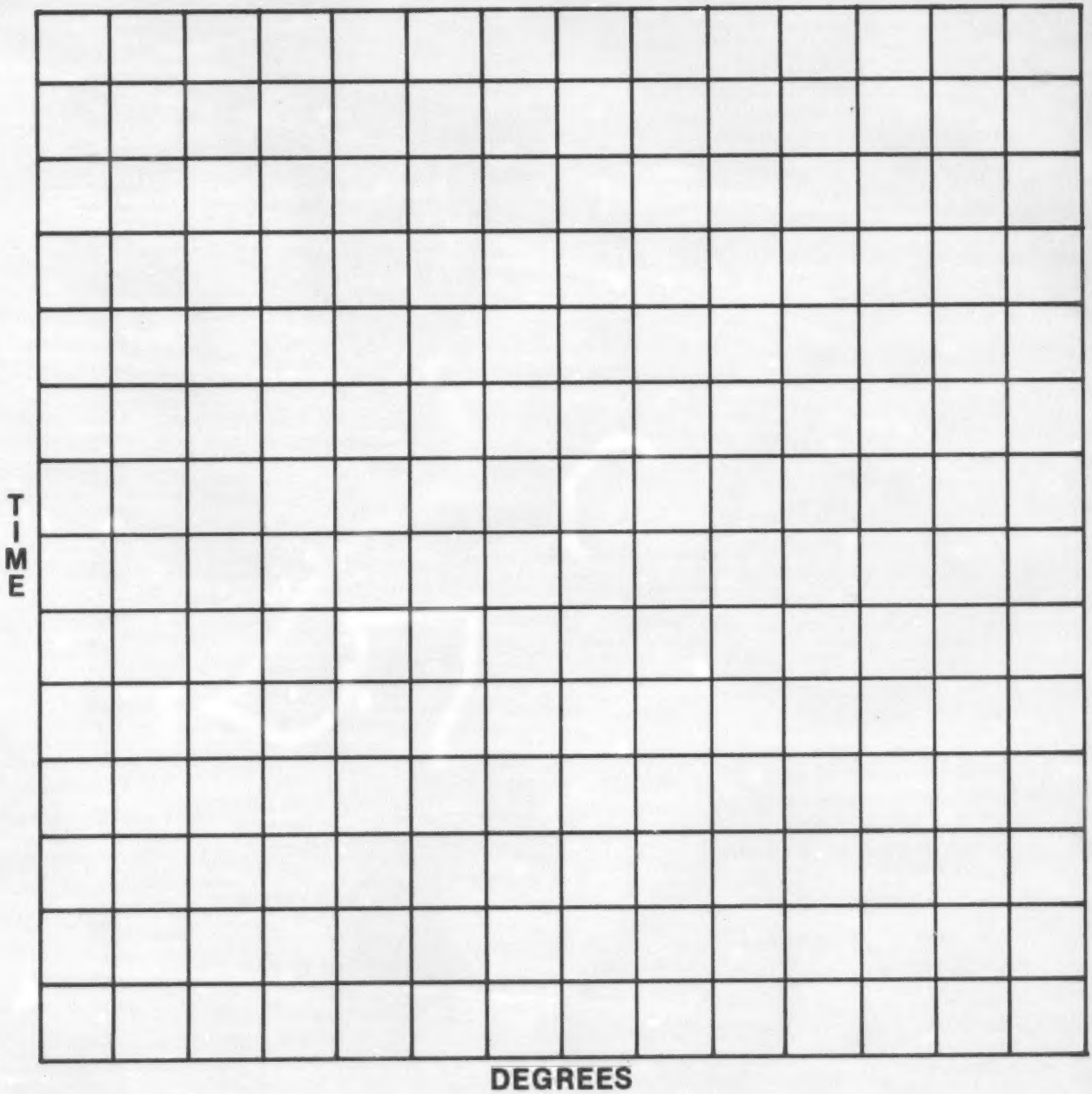
5. Besides overindulgence, what is a very real hazard of drinking any home-made alcoholic beverage?

6. Give as many pieces of evidence as you can to prove that the bulk of the liquid you distilled at 78°C was ethanol.

Name _____

Date _____

7. (Optional) Make a graph of temperature vs. time for this experiment.



Heat of Combustion of Ethyl Alcohol $\text{CH}_3\text{CH}_2\text{OH}_{(1)}$

Concept

Making ethyl alcohol from grain or sugar beets.

Question

How can ethanol be produced?

Objectives

Students will be able to observe the fermentation and distillation processes taking place.
Students will be able to gather ethanol.
Students will be able to measure heat lost by the complete combustion of ethyl alcohol.

Process Skills

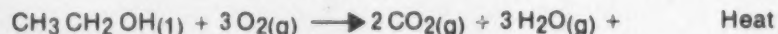
calculating, hypothesizing, identifying, measuring, observing, recording

Time

To be determined by the instructor

Background

The following equation shows the complete combustion (burning) of ethyl alcohol:



The problem in this experiment is to determine the heat (in Kcal and BTU) produced by the burning of ethyl alcohol. Heat is a form of energy. The three units most commonly used in measuring the quality of heat are:

- (a) 1 calorie (cal) = the heat required to raise the temperature of one gram of water 1°C
- (b) 1 kilocalorie (Kcal) = 1,000 calories, or the heat required to raise the temperature of 1 liter of water 1°C
- (c) 1 British Thermal Unit (BTU) = the heat to raise the temperature of 1 lb. of water 1°F .

Since 1 lb. = 453.6 grams and $1^\circ\text{F} = 5/9^\circ\text{C}$

Then

$$1 \text{ BTU} = 453.6 \times 5/9 \text{ cal} = 252 \text{ calories}$$

or

$$1 \text{ BTU} = 0.252 \text{ Kcal}$$

In this experiment students will measure the heat lost by the complete combustion (burning) of ethyl alcohol, the 10 percent component of Gasohol, by determining the heat gained by a container of water held above the burning ethyl alcohol. The heat gained by the water can be calculated using the following equation:

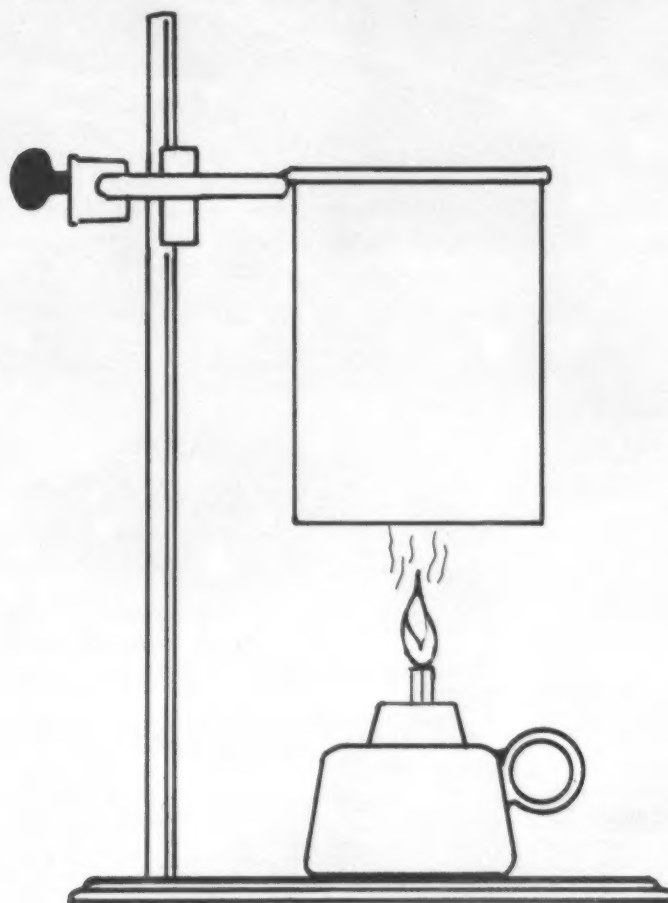
$$\text{Heat gained by} = \text{mass} \times \text{specific heat} \times \text{temp. change a body (cal)}$$

Materials:

- 1. denatured ethyl alcohol, $\text{CH}_3\text{CH}_2\text{OH}_{(1)}$
- 2. glass alcohol burner
- 3. ring stand and ring clamp
- 4. soup can with two holes punched in the sides of the open end
- 5. balance
- 6. thermometer $^\circ\text{C}$

Procedure

- A. Fill the glass alcohol burner with the ethyl alcohol, $\text{CH}_3\text{CH}_2\text{OH}$, and weigh the filled burner on the balance and record the mass in the "Data Table."
- B. Weigh the empty can on the balance and record the mass in the "Data Table."
- C. Fill the weighed can about two-thirds full with cold tap water. Cool the water with ice if necessary so that its temperature is about 10 to 15°C below room temperature. Add the ice directly to the water. Remove any remaining ice when the desired temperature has been reached.
- D. Set up the following apparatus:



- E. Read and record the temperature of the water in the can, and record it in the "Data Table."
- F. Light the alcohol burner and adjust the can so the bottom is in the hottest part of the flame. Continue heating the water, stirring it gently, until it reaches a temperature about as much above room temperature as it was below at the start. The following reaction shows the complete combustion (burning) of the ethyl alcohol.



The heat produced by the burning ethyl alcohol is absorbed by the water in the can.

- G. Blow out the alcohol burner, continue to stir the water, while watching the thermometer reading, until the highest temperature is reached. Record this temperature in the "Data Table."
- H. Next weigh the alcohol burner on the same balance that was used to weigh it in the beginning. Record the mass in the "Data Table."
- I. Weigh the can and water on the balance and record the weight in the "Data Table."
- J. Clean up and return the materials, then complete the "Data Table."

Gasohol: An Energy Alternative

Heat of Combustion of

Ethyl Alcohol

$\text{CH}_3\text{CH}_2\text{OH}(1)$

Page 3

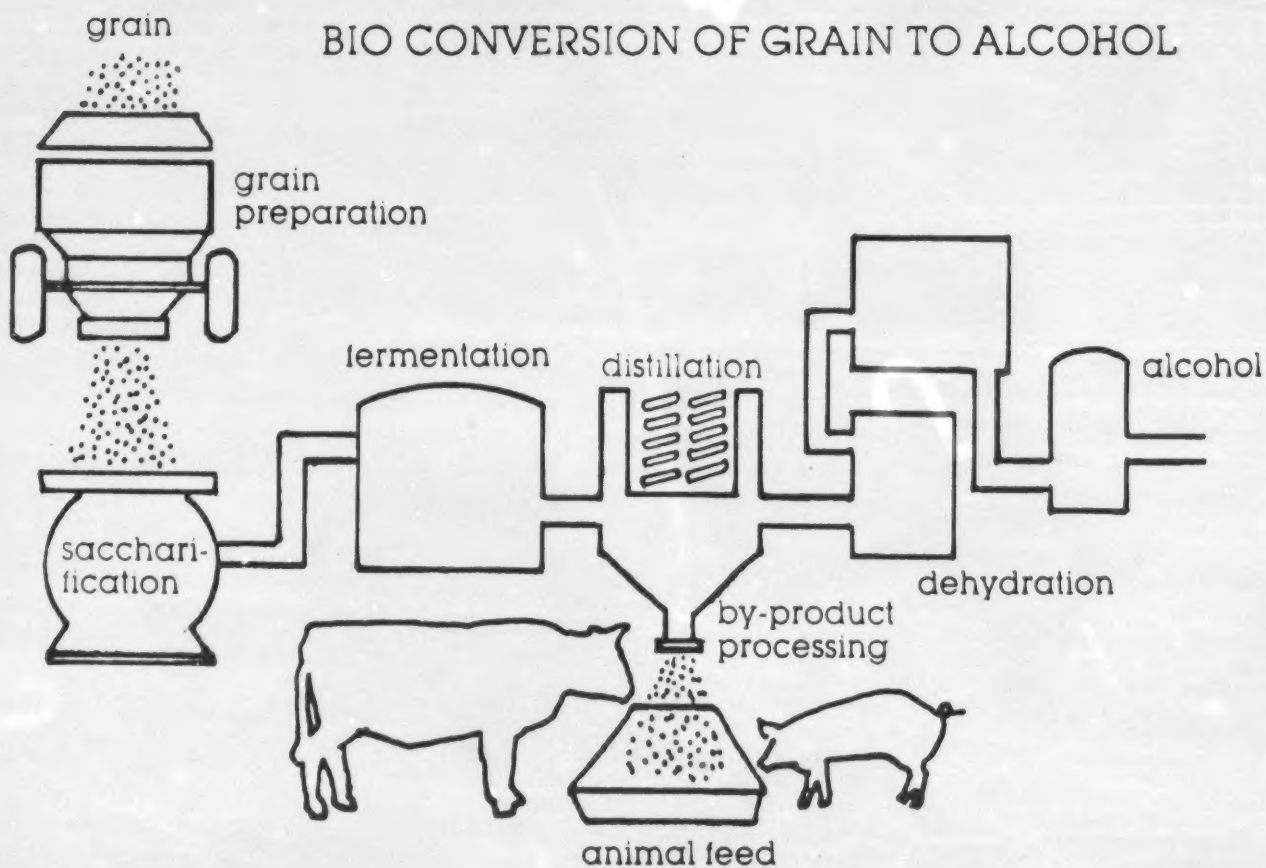
Name _____

Date _____

Data Table

1. Weight of alcohol burner at the start of the experiment..... _____ grams
2. Weight of the alcohol burner at the end of the experiment..... _____ grams
3. Weight of the ethyl alcohol, $\text{CH}_3\text{CH}_2\text{OH}$ burned during the experiment _____ grams
4. Weight of the empty can _____ grams
5. Weight of the can plus the heated water _____ grams
6. Weight of just the water in the can which absorbed the heat from the burning ethyl alcohol _____ grams
7. Temperature of the water in the can at the start of the experiment _____ °C
8. Temperature of the water in the can at the end of the experiment _____ °C
9. Change in the temperature of the water..... _____ °C

T = _____ °C



Gasohol: An Energy Alternative

Heat of Combustion of

Ethyl Alcohol

$\text{CH}_3\text{CH}_2\text{OH}(l)$

Page 4

Name _____

Date _____

Calculations and Problems

Directions: Calculate the following and record your answers.

1. Calculate the quantity of heat (calories) released by the burning ethyl alcohol to warm the water in the can. Assume that all of the heat from the burning alcohol was used in heating only the water.

HINT: Heat gained = mass x specific heat x temp. change

specific heat = _____ calories of heat absorbed by the water in the can
water

2. Calculate the number of moles of ethyl alcohol burned in the experiment

_____ moles of $\text{CH}_3\text{CH}_2\text{OH}$
burned

3. Calculate the number of kilocalories of heat (Heat of Combustion) produced by burning one mole of ethyl alcohol, according to your experimental data.

Convert this to Btu/mole

_____ Kcal/mole

_____ Btu/mole

4. The Handbook of Physics and Chemistry lists the Heat of Combustion of ethyl alcohol as:

Heat of Combustion of $\text{CH}_3\text{CH}_2\text{OH}$ = 327.6 Kcal/mole
(ethyl alcohol)

Convert this to Btu/mole and Btu/gallon

_____ Btu/mole

_____ Btu/gallon

5. How does your experimental value for the Heat of Combustion for ethyl alcohol (Question 3) compare with the "Handbook" value? Higher or Lower: _____

Explain the reason why they differ:

6. The following reaction shows the complete combustion of wood alcohol, CH_3OH . Balance the equation:



A student found by burning 1 gram of methyl alcohol he produced 10.69 Kcal of heat. Calculate the Heat of Combustion (Kcal/mole) for methyl alcohol using this data.

Heat of Combustion = _____

Kcal/mole
 CH_3OH

Gasohol: An Energy Alternative

Heat of Combustion of

Ethyl Alcohol

$\text{CH}_3\text{CH}_2\text{OH}$

Page 5

Name _____

Date _____

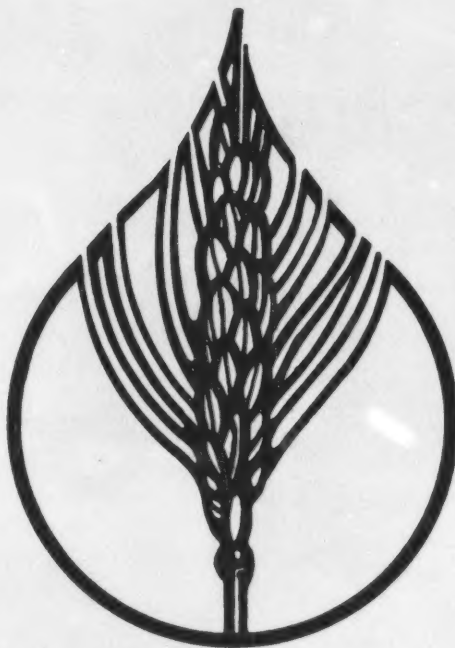
Additional Problems

Directions:

Calculate and solve the following:

1. How many calories are required to heat each of the following 15°C to 65°C :
 - a. 100 grams of water _____
 - b. 5 grams of pyrex glass (Hint: specific heat of pyrex glass is 0.20) _____
 - c. 20 grams of platinum (Hint: specific heat of platinum = 0.032) _____
2. How many Btu are removed in cooling each of the following from 212°F to 68°F :
 - a. 1 lb. of water _____
 - b. 2 lbs. of leather (Hint: specific heat of leather = 0.36)

 - c. 3 lbs. of asbestos (Hint: specific heat of asbestos = 0.20)



Gasohol: An Energy Alternative

Heat of Combustion of

Ethyl Alcohol

$\text{CH}_3\text{CH}_2\text{OH}(l)$

Page 6

Name _____

Date _____

3. The combustion of 5.0 grams of coal raised the temperature of one liter of water from 10°C to 47°C . Calculate the Heat of Combustion of coal in Kcal/gram.
- _____
4. Fuel oil has a Heat of Combustion of 19,000 Btu/lb. Assuming that 70% of the heat is absorbed and 30% is lost, how many pounds of oil are required to heat 1000 lbs. of water from 50°F to 190°F ?
- _____
- 5a. Show the balanced reaction for the complete combustion of ethane gas, C_2H_6 :
- _____ $\longrightarrow$ _____
- 5b. Burning 5 grams of ethane produced 62.17 Kcal of heat. Calculate the Heat of Combustion of ethane:
- _____ Kcal/mole
- 5c. Assuming that 60 percent of the heat is absorbed and 40 percent lost, calculate how many liters of ethane at S.T.P. must be burned to supply enough heat to raise the temperature of 50 kilograms of water at 10°C to steam at 100°C .
- _____ liters
- 6a. Show the balance of the equation for the complete combustion of natural gas, $\text{CH}_4(g)$:
- _____ $\longrightarrow$ _____
- 6b. Burning 4 grams of natural gas produced 53.25 Kcal of heat. Calculate the Heat of Combustion of natural gas:
- _____ Kcal/mole
- 6c. Assuming that 50 percent of the heat is absorbed and 50 percent lost, calculate how many kilograms of water at 15°C could be heated to 95°C by burning 200 liters of natural gas, $\text{CH}_4(g)$, at S.T.P.?
- _____ Kilograms of water

Answers for "Calculations and Problems" 1-6 will vary according to data of your particular experiment.

Answers for "Additional Problems" 1-6c are:

1a. 5,000 calories or 5 kilocalories

1b. 50 calories

1c. 32 calories

2a. 144 Btu

2b. 104 Btu

2c. 86 Btu

3. 7.4 Kcal/gram

4. 10.5 lbs.

5a. $\text{C}_2\text{H}_6 + \frac{1}{2}\text{O}_2(g) \longrightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(g) + \text{Heat}$

5b. 373 Kcal/mole

5c. 3150 liters of ethane

6a. $\text{CH}_4(g) + 2\text{O}_2(g) \longrightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(g) + \text{Heat}$

6b. 213 Kcal/mole

6c. 11.9 Kilograms

Enzymatic Production of Alcohol

Concept

Producing ethanol from corn using industrial enzymes

Question

How much ethanol can be produced from 100 g of ground corn?

Objectives

Students will be able to record three (3) days of observations.

Students will be able to assist in performing the experiments.

Process Skills

gathering data, hypothesizing, identifying, measuring, observing, recording

Time

4-5 days

Background

Contained herein is an experiment for the production of ethanol from corn using industrial enzymes and information on how to obtain a license to make alcohol. This experimental procedure has been thoroughly classroom tested with excellent results.

The basic chemical changes involved with ethanol production from corn should be covered with students before beginning.

All necessary equipment can be found in a high school chemistry lab. You will need to produce the enzymes Teka-Therm and Diazyme L-100 (both liquids). Here are some places where these enzymes can be purchased cheaply and quickly:

RE: Sources of Alcohol Plant Equipment

Please be advised that the attached list of equipment suppliers are those who have indicated an interest in supplying turnkey units or component parts for alcohol production facilities. In most cases, these firms have experience in engineering and design of alcohol production facilities and are recognized for their experience in this area. However, some firms may have only limited experience in this field. The firms listed are not to be considered as recommended by the Nebraska Gasohol Committee. The firms are listed only as a reference and, as in any business, you should check the experience and credentials of any firm prior to entering into a contract or agreement to purchase systems or component parts.

Anheuser Busch
St. Louis, MO
Yeast & enzymes

Aquaterra Biochemicals Corp.
P.O. Box 496
Lancaster, TX 75146
(214) 227-6960
Enzymes

Enzyme Development Corporation
Executive Office: 2 Penn Plaza
New York, NY 10001
(212) 736-1580
Enzymes

Fermco Biochemicals, Inc.
2638 Delton Lane
Elk Grove Village, IL 60007
(312) 595-3131
Enzymes & yeast

G.B. Fermentation Industries, Inc.
One North Broadway
Des Plaines, IL 60061
(312) 827-9700
Enzymes & yeast

Miles Laboratories, Inc.
Enzyme Products Division
P.O. Box 932
Elkhart, IN 56515
(219) 564-8111
Yeast & enzymes

Norbert Haverkamp
Rural Route 1, Box 114
Horton, KS 66439
(913) 486-3302
Yeast & enzymes

Premier Malt Products, Inc.
1037 West McKinley Avenue
Milwaukee, WI 53201
(414) 347-7469
Enzymes

Rahm and Haas
Independence Mall West
Philadelphia, PA 19105
(215) 592-2517
Enzymes & yeast

Red Star Yeast
DADY
Universal Foods Corporation
P.O. Box 737
Milwaukee, WI 53201
(414) 271-6755
Yeast

Schwarz Service International LTD.
230 Washington Street
Mt. Vernon, NY 10551
(914) 664-1100
Enzymes & yeast

Yeast Products Research
Anheuser-Busch, Inc.
721 Pestalozzi Street
St. Louis, MI 63113
Yeast and enzymes

Background Schedule

Monday

Pass out experimental sheets to all students. Read over carefully. Obtain all needed equipment for Day 1.

Tuesday

Finish day 1 activities. If you work with a 1 hour period, you must start immediately to finish on time.

Wednesday

Complete day 2 activities. This will take only about 30 minutes, so plan to set up the distillation equipment needed for day 3 in the remaining time.

Thursday

Complete day 3 activities. You can distill on Thursday, but your percent of alcohol yield will be higher on Friday.

An added flare to this experiment on Day 1 is the iodine test. Perhaps the instructor can do this test while students are working. Iodine will form a blue complex in the presence of soluble starch. It will retain its reddish appearance if no starch is present. (It was found that by taking a sample of the mash solution and running it in a centrifuge one could get a clear substrate to test).

You can expect anywhere from 16-22 ml of .80-.85 g/ml density ethanol, depending on your distillation equipment and skills.

Materials (per student pair)

500 or 1,000 ml beaker	pH paper	10 ml graduated cylinder
100 g ground corn	condenser tube (cooling jacket)	glass funnel
gram balance	ring stand clamps	liquid iodine
ring stand	wire gauze	dilute sulfuric acid
.5 ml Teka-Therm	thermometer	hydrated lime
.5 ml Diazyme L-100	stirring apparatus (may be stirred manually)	boiling chips or cracked marbles
3g yeast	rubber tubes	boiling flask
2g of yeast nutrient or sugar	hot plate, heating jacket or bunsen burner	

Caution

In order to produce alcohol legally, even in small amounts at a high school, you must first get a license from the federal government. A two year bond-free permit is available for experimenters who produce under 10,000 proof gallons a year.

A letter must be sent to the Bureau of Alcohol, Tobacco, and Firearms. The letter should include:

- A. The **Nature and Purpose** of your plant;
- B. A description of **Plant Premises**;
- C. A description of **Production and Equipment**;
- D. A description of **Security** you will take to protect your alcohol and equipment.
- E. Your estimated **Rate of Production** for any 15 consecutive days; and
- F. A description of your **Waste Disposal Methods**.

There is no special form for the application. The letter should be sent in duplicate to the address below. A copy of Lakeview's letter of application and license follows.

For more information, write or call:

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco and Firearms
15th Floor
230 South Dearborn Street
Chicago, Illinois 60604
Phone: (312) 886-5149

Procedure/Sequence

DAY #1

Wear lab vests and goggles!

1. Weigh a clean, dry 1,000ml beaker.
2. Weigh in 100g of corn. Grind to a "chunky" consistency. (A meat grinder works well for this).
3. Add 300ml of water and stir. Check the pH of the solution. Adjust to a pH of 7, if needed, by slowly adding dilute sulfuric acid if the pH is high or hydrated lime if the pH is low.
4. Measure out .5ml of the enzyme Teka-Therm and stir into the mash.
5. Begin heating the mash. Increase the temperature to 66°C and hold it there for 30 minutes. At this point you are liquifying the starches with Teka-Therm.
6. After 30 minutes, starch should be present as indicated by the iodine test. Iodine forms a blue complex in the presence of starch. (optional)
7. Continue heating, and bring the mash to a boil. Then, shut off the heat and let mixture cool (water may be added to accelerate this) to 60°C.
8. Adjust the pH of the mash to 4.
9. Stir in .5ml of Diazyme-L100. The Diazyme converts the starch to sugar, which the yeast can digest.
10. Continue checking the starch and sugar content with the iodine test, hopefully only sugar is now present.
11. Let the mash set overnight.

DAY #2

12. Check the temperature of the mash. Yeast grow best if the temperature is between 22-26°C.
13. Weigh out 3g of yeast and 2g of yeast-nutrient or sugar. Mix together in a small beaker of warm water and let set for 5 minutes. This will give the yeast a chance to activate before being placed in the harsh environment of the mash.
14. Add the yeast solution and mash to a 500 or 1,000ml flask. Swirl gently.
15. Cork the flask and set up the fermentation apparatus (see figure #1). The yeast will now consume the sugar, producing ethanol and carbon dioxide in this anerobic process.

DAY #3

Wear lab vests and goggles!

16. Stop in after school and between periods to check the progress.
17. Strain the corn from the liquid using a funnel and screen. The corn may be dried. It is now called Distillers Dried Grain (D.D.G.), and is quite high in protein content.
18. Pour the liquid into a boiling flask and add boiling chips. Set up the distillation apparatus (see diagram #2).
19. Heat the mixture and keep the temperature below 85°C. The temperature may be controlled by the intensity of heat or the flow rate of the water.
20. Check the alcohol's density and burning properties. Pure ethanol should have a density of about .8 g/ml.

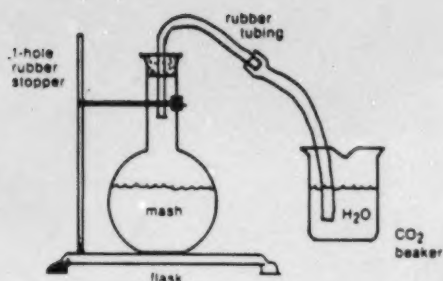


DIAGRAM I:
 Fermentation apparatus. The flask contains the mash and yeast. The tube leading into the water prevents the reentry of air, thus creating an anerobic growth situation in the flask.

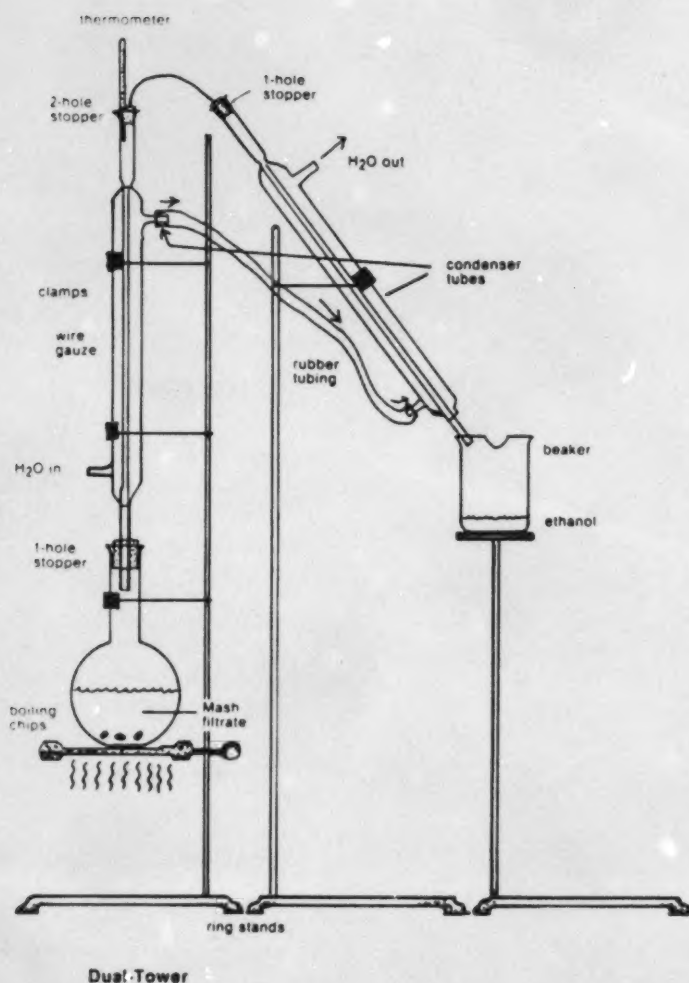
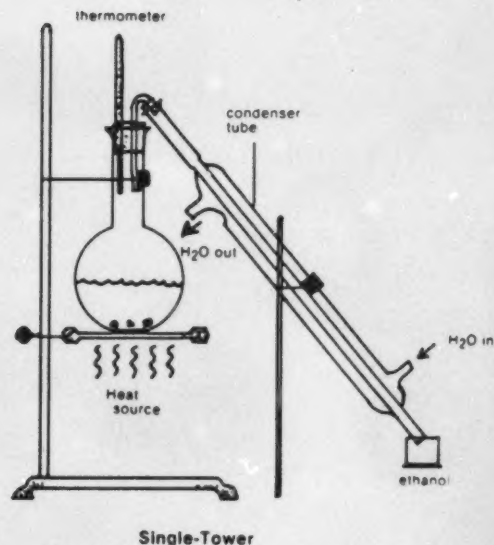


DIAGRAM II:
 Distillation apparatus. Make sure boiling chips are placed in the boiling flask. Either set-up may be used, but the dual-tower will give a better yield with less H₂ carryover.



Gasohol: An Energy Alternative
Producing Ethanol From Corn
Student Data Sheet, Page 1

Name _____

Date _____

Directions: Complete the following statements throughout the experiment.

1. Total water used: _____
2. Fermentation Period: _____
3. ml of ethanol produced: _____
4. Density of ethanol produced: _____
5. Percent of corn converted to ethanol: _____

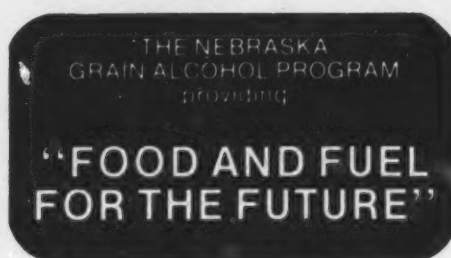
Observations

Day 1

Day 2

Day 3

Conclusions



April 9, 1980

Bureau of Alcohol, Tobacco and Firearms
230 South Dearborn Street
Chicago, IL 60604

Dear Sirs:

Lakeview High School is applying for a two-year alcohol permit for classroom demonstration purposes only.

Nature and Purpose

We intend to test several sources of fermentable carbohydrates (corn, wheat, oats, barley and cellulose) with yeast to produce ethyl alcohol. We plan to distill the alcohol, and test it in a small internal combustion engine (a lawn mower engine).

The purpose is to show chemistry students (grade levels 11 and 12) the viability of grains as a potential fuel source.

Description of the Plant Premises

The location of our chemistry lab is six miles north of Columbus, NE, Lakeview High School. The lab has passed all State Fire inspections and has all necessary safety equipment (blast hood, goggles, lab fire extinguisher, and fire blankets).

Description of Production Process and Equipment

Mash will be combined with water, sugar, and yeast, stored in flasks, covered and stored in the blast hood. The mash will be separated by filtration and distilled by a simple cooling jacket.

Security

All alcohol produced will be kept in a one gallon metal gas can. This can will be stored in the Lakeview lab under lock and key.

Rate of Production

Approximately ten liters (about 2.5 gallons), averaging 160-190 proof will be produced in this period.

Ed Kinzer
Lakeview High School
Chemistry Teacher

Richard Kamm
Lakeview High School
Superintendent

Don Schmidt
Lakeview High School
Principal

Gasohol: An Energy Alternative
Producing Ethanol From Corn
Sample Permit

Instructor Information . . .

This is an example of the permit you should receive. It must be displayed near the area where the alcohol is being produced.

DEPARTMENT OF THE TREASURY — BUREAU OF ALCOHOL, TOBACCO AND FIREARMS EXPERIMENTAL DISTILLED SPIRITS PLANT PERMIT UNDER 26 U.S.C. 5312(b)	1. PERMIT NUMBER X-DSP-NE-113 2. EFFECTIVE DATE April 17, 1980 3. DATE OF APPLICATION April 9, 1980 4. EXPIRATION DATE April 17, 1982
5. NAME OF PERMITTEE AND ADDRESS OF PERMIT PREMISES LAKEVIEW HIGH SCHOOL Route 3, Box 170 Columbus, Nebraska 68601	
THIS PERMIT IS GRANTED FOR EXPERIMENTATION OR DEVELOPMENT OF SOURCES OF MATERIALS FROM WHICH SPIRITS MAY BE PRODUCED; PROCESSES BY WHICH SPIRITS MAY BE PRODUCED OR REFINED; OR INDUSTRIAL USES OF SPIRITS.	
6. LIMITATION	
Pursuant to application and subject to applicable law and regulations and to the conditions set forth on the reverse side of this permit, you are hereby authorized and permitted to engage, at the above address, in the operations specified herein. This permit will remain in force until suspended, revoked, voluntarily surrendered, or automatically terminated on the expiration date noted above. This permit is not transferable. In the event of any lease, sale, or other transfer of the operations authorized, or of any other change in the proprietor of such operations, this permit shall automatically terminate. (If permittee is a corporation or partnership, see reverse side.)	
7. SIGNATURE OF REGIONAL REGULATORY ADMINISTRATOR, BUREAU OF ALCOHOL, TOBACCO AND FIREARMS	

Your permit will look like this. It must be displayed near the area where the alcohol is being produced.

"Sample Problem List"

Rationale:

After students have had an opportunity to explore the various components of gasohol, you may want to have them test their skills and knowledge by doing some or all of the following problems.

Objectives:

Students will be able to solve some or all of the sample problems.

Implementation:

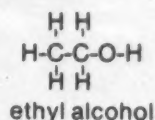
Distribute as many of the sample problem pages as is appropriate.

Debriefing:

It may be necessary for you to work through these problems with students.

Directions: Solve the following problems

1. Gasohol is a blend of 10% agriculturally derived 200 proof anhydrous ethyl alcohol and 90% of unleaded gasoline. Ethyl alcohol (ethanol) is an organic compound with the following empirical formula, C_2H_6O . The structural formula for ethyl alcohol is shown below.



List the structural formula for a structural isomer of ethyl alcohol:

(Isomer)

2. To complete the combustion of natural gas, $CH_4(g)$, is shown in the following reaction:

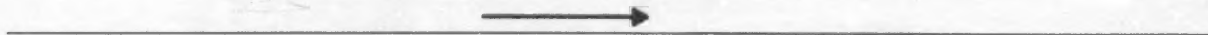


Gasohol is a blend of 10% ethyl alcohol, CH_3CH_2OH , and 90% unleaded gasoline, C_8H_{18}

- (a) Show the balanced equation for the complete combustion of ethyl alcohol, the 10% component of Gasohol:



- (b) Show the balanced equation for the complete combustion of octane, C_8H_{18} :



3. Gasohol is a blend of 10% ethyl alcohol, CH_3CH_2OH produced from the fermentation of grains. Answer the following questions for ethyl alcohol:

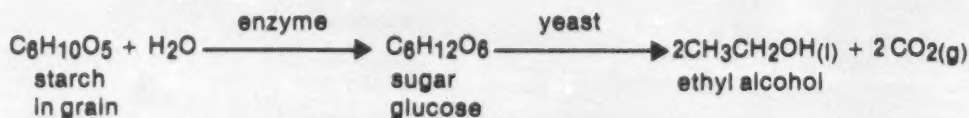
(a) Is it an organic or inorganic compound? _____

(b) What is the mass of one mole of ethyl alcohol? _____ g/mole

(c) Calculate the volume of one mole of ethyl alcohol in ml. Density of ethyl alcohol = 0.789 grams/ml
_____ ml/mole

(d) Calculate the percent by weight of carbon in ethyl alcohol. _____ % by wt. of carbon

4. A bushel of corn can be converted to 2.5 gallons of ethyl alcohol in a Gasohol plant by the following reaction (glycolysis): 1 gallon = 3,785 ml.



Calculate the number of moles of glucose that would be needed to produce 2.5 gallons of ethyl alcohol.

_____ moles of ethyl alcohol

5. Write the balanced equation for the production of glucose by photosynthesis:



6. The total amount of solar energy required in the production of a bushel of corn is approximately 1×10^9 Btu. The recoverable energy from the 2.5 gallons of ethyl alcohol produced by a bushel of corn is about 2.7×10^4 Btu. What is the efficiency in this conversion?

_____ %

7. The complete combustion of octane, C_8H_{18} , a component of gasoline is shown below. Balance the equation:



The density of octane = 0.7036 grams/ml
one gallon = 3.7853 liters

Using the above information calculate the number of liters of oxygen required for the complete combustion of one gallon of octane at S.T.P.

_____ liters of $O_2(\text{g})$

8. The complete combustion of ethyl alcohol, 10% component of Gasohol, is shown in the following reaction. Balance the equation:



The density of ethyl alcohol = 0.789 grams/ml one gallon = 3.7853 liters

Using the above information calculate the number of liters of oxygen required for the complete combustion of one gallon of ethyl alcohol at S.T.P.

_____ liters of $O_2(\text{g})$

9. Below is a table of exhaust gases from two test vehicles obtained by the ERDA Energy Research Center comparing Gasohol and unleaded gasoline:

Data Table

Component in exhaust	Gasohol grams/mile	No-lead Gasoline grams/mile
A. carbon monoxide $\text{CO}(\text{g})$	15.4	23.1
B. unburned hydrocarbons HC	1.8	2.0
C. nitrogen oxides NO_x	2.4	2.7
D. carbon dioxide $\text{CO}_2(\text{g})$	751.9	768.9

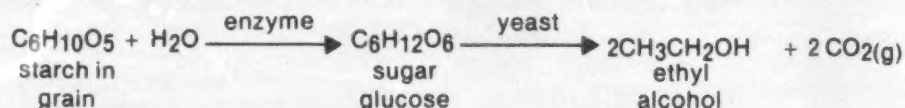
Gasohol: An Energy Alternative**Sample Problem List**

Page 3

Name _____

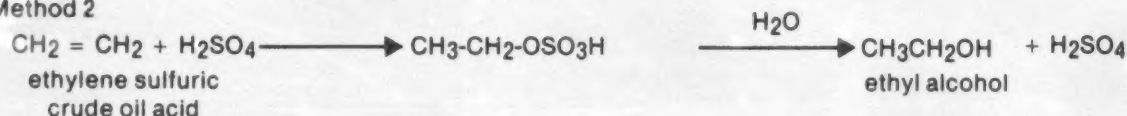
Date _____

10. There are two methods used in the production of ethyl alcohol, $\text{CH}_3\text{CH}_2\text{OH}$. Method 1 is by fermentation of carbohydrates, which is used to make the ethyl alcohol in Gasohol production:



Method 2 is by hydration of alkenes obtained from the cracking of crude oil:

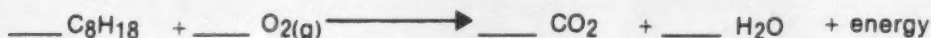
Method 2



At the present time most of the synthetic ethyl alcohol produced in this country (250 million gallons a year) is done using Method 2. If you started with one kilogram of ethylene and recovered 689.92 grams of ethyl alcohol, what would be your percent yield? Assume an excess of all other ingredients.

_____ % yield

11. A chemical component of gasoline is 2,2,4-trimethyl pentane. Using a set of ball and stick models, build a molecule of this compound.
12. The chemical name for grain alcohol is ethanol, which is ethane with an -OH group substituted for an -H. Using a set of ball and stick models, build a molecule of ethanol.
13. The density of gasoline is 0.692 grams/cc. How many grams of gasoline are there in one gallon of gasoline? (Hint: one gallon contains 3.785 cc)
- _____ grams
14. The density of pure ethanol, $\text{CH}_3\text{CH}_2\text{OH}$, is 0.789 gm/cc. How many grams of ethanol are there in one gallon of ethanol? (Hint: One gallon contains 3.785 cc)
- _____ grams
15. When gasoline burns completely, the following equation describes what happens. Balance the equation:



16. When pure ethanol burns completely, the following equation describes what happens. Balance the equation including heat as a product:



17. Use the balanced equation for the complete combustion of octane along with the heat of formation values listed below to calculate how many Kilocalories of energy are contained in one gallon of gasoline, C_8H_{18} . (Hint: First calculate the Heat of Combustion using the H_f values)

$$H_f \text{ C}_8\text{H}_{18} = 51.97 \text{ Kcal/mole}$$

$$H_f \text{ CO}_2 = 94.05 \text{ Kcal/mole} \quad \text{Kcal/mole octane, C}_8\text{H}_{18}$$

$$H_f \text{ H}_2\text{O} = 57.80 \text{ Kcal/mole} \quad \text{Kcal/gallon}$$

Gasohol: An Energy Alternative**Sample Problem List**

Page 4

Name _____

Date _____

18. Use the balanced equation for the complete combustion of ethanol along with the heat of formation values listed below to calculate how many Calories of energy are contained in one gallon of pure ethanol, C_2H_5OH .

$$H_f C_2H_5OH = 56.24 \text{ Kcal/mole}$$

$$H_f CO_2 = 94.05 \text{ Kcal/mole}$$

$$H_f H_2O = 57.80 \text{ Kcal/mole}$$

_____ Kcal/mole
ethyl alcohol
 C_2H_5OH
_____ Kcal/gallon

19. Gasohol is a mixture of pure ethanol, C_2H_5OH , and unleaded gasoline. Here is how the Gasohol is mixed:

0.900 of a gallon of unleaded gasoline is mixed with 0.100 of a gallon of pure alcohol

The result is surprising. The volume increases ever so slightly to 1.002 gallons! Using the energy values of 110,400 Btu per gallon for the burning of gasoline and 78,600 Btu per gallon for the burning of pure ethanol, calculate the energy obtained from burning one gallon of Gasohol.

_____ Btu/gallon
of Gasohol

20. Wood can be heated in a tube with limited oxygen supply so that the wood "distills" rather than burns. That is, the cellulose in the wood breaks up into simpler molecules. One of these "simpler" molecules is methanol, which may be used as a gasoline additive or substitute. During World War II, many Europeans drove "wood burning" cars, because gasoline was in short supply. These vehicles had small wood "stills" mounted on them which produced some methanol, CH_3OH , by distillation, which was then burned. This was not a good system but it worked in a pinch.

- (a) If you assume that the formula for wood is $C_{32}H_{46}O_{23}$, and that 40% of the wood is converted to methanol by heating, how many kilograms of methanol can be obtained from 1.000 kilogram of wood?

_____ kilograms of
methanol

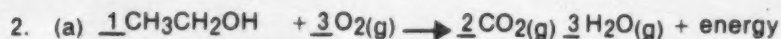
- (b) If this methanol is burned according to the following reaction, balance the equation:



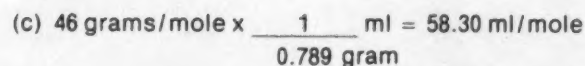
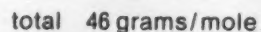
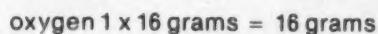
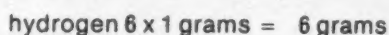
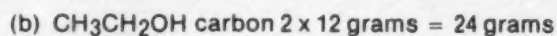
If you were to burn all of the wood alcohol produced in Part (a), how much heat is produced? The ΔH for the above reaction is -170.19 Kcal/mole

_____ Kcal

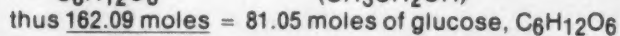
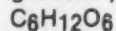
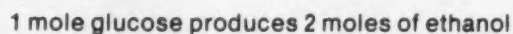
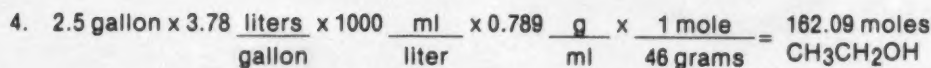
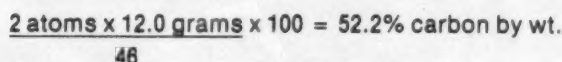
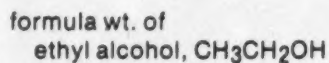
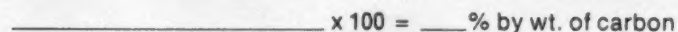
1. Structural isomer for C_2H_6O : CH_3-O-CH_3



3. (a) Organic — carbon chain containing compound



- (d) Number of carbon x atomic wt. of
atoms carbon





to make 81.05 moles of glucose requires $6 \times 81.05 = 486.3$ moles H_2O

$$486.3 \text{ moles H}_2\text{O} \times \frac{18 \text{ g}}{\text{mole}} \times \frac{1 \text{ ml}}{\text{g}} \times \frac{1 \text{ liter}}{1000 \text{ ml}} = 8.75 \text{ liter H}_2\text{O}$$

6. $\frac{2.7 \times 10^4 \text{ Btu}}{1 \times 10^8 \text{ Btu}} \times 100 = 2.7 \times 10^3 \text{ or } 0.0027$

7. Step 1 Calculate the number of grams of octane in one gallon:

$$1 \text{ gal} \times 3.7853 \frac{\text{L}}{\text{gal}} \times \frac{1000 \text{ ml}}{\text{L}} \times 0.7036 \frac{\text{g}}{\text{ml}} = 2663.34 \frac{\text{grams}}{\text{gal}}$$

Step 2 Calculate the number of moles of octane:

$$2663.34 \frac{\text{g}}{\text{gal}} \times \frac{1 \text{ mole}}{114.23 \text{ g}} = 23.316 \frac{\text{moles}}{\text{gal}}$$

Step 3 Using the balanced equation calculate the number of moles of oxygen required:

$$23.316 \text{ moles octane} \times 12.5 \frac{\text{mole oxygen}}{\text{mole octane}} = 291.45 \text{ moles oxygen}$$

Step 4 Convert moles of oxygen to liters:

$$291.45 \text{ moles oxygen} \times 22.4 \frac{\text{Liters}}{\text{mole}} = 6528.48 \text{ liters of oxygen}$$

8. Step 1 Calculate the number of moles of ethyl alcohol in one gallon:

$$1 \text{ gallon} \times 3.7853 \frac{\text{liters}}{\text{gal}} \times \frac{1000 \text{ ml}}{\text{L}} \times 0.789 \frac{\text{g}}{\text{ml}} \times \frac{1 \text{ mole}}{46.07 \text{ g}} = 64.83 \frac{\text{moles}}{\text{gal}}$$

Step 2 Using the balanced equation calculate the volume of oxygen required:

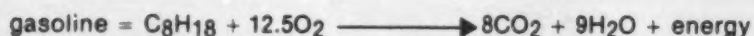
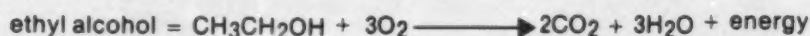
$$64.83 \text{ moles ethyl alcohol} \times 3 \frac{\text{moles oxygen}}{\text{moles ethyl alcohol}} \times 22.4 \frac{\text{liters}}{\text{mole oxygen}} = 4356.8 \text{ liters oxygen at S.T.P.}$$

Gasohol: An Energy AlternativeSample Problem List
Page 3, Answer Sheet**Instructor
Information . . .**

$$9. \quad (a) \quad \frac{15 \text{ miles}}{\text{gal}} \times \frac{15.4 \text{ grams}}{\text{mile}} = \frac{\text{grams CO}}{\text{gal of Gasohol}}$$

$$(b) \quad \frac{15 \text{ miles}}{\text{gal}} \times \frac{23.1 \text{ grams}}{\text{mile}} = \frac{346.5 \text{ grams CO}}{\text{gal of No-Lead gasoline}}$$

(c) The additional CO produced by the No-Lead gasoline can be explained using the balanced equations for complete combustion:



It requires more oxygen for the complete combustion of gasoline.

10. Step 1 Calculate the number of moles in 1 kilogram of ethylene

$$\frac{1000 \text{ gram}}{\text{kilogram}} \times \frac{1 \text{ moles}}{\text{grams}} = \frac{35.71 \text{ moles}}{\text{kilogram}}$$

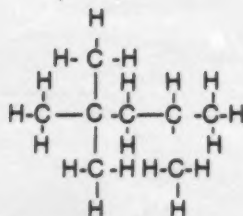
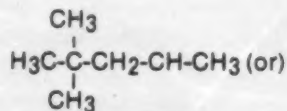
Step 2 Calculate the theoretical yield of ethyl alcohol using the balanced equation:

35.71 moles of ethylene could produce 35.71 moles of alcohol. Convert this to grams:

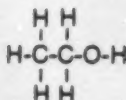
$$\frac{35.71 \text{ moles} \times 46 \text{ grams}}{\text{mole}} = 1642.66 \text{ grams } 100\% \text{ yield ethyl alcohol}$$

$$\text{Step 3 } \% \text{ yield} = \frac{\text{Exp. yield}}{\text{theoretical yield}} \times 100 = \frac{689.92 \text{ grams}}{1642.66 \text{ grams}} \times 100 = 42\%$$

11. 2, 2, 4 - trimethyl pentane

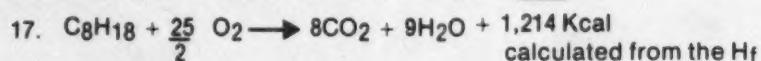
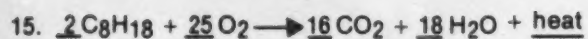


12. Ethanol
(ethyl alcohol) $\text{CH}_3\text{CH}_2\text{OH}$ OR



$$13. \quad \frac{0.692 \text{ gm}}{\text{cc}} \times 3,785 \frac{\text{cc}}{\text{gal}} = 2.62 \times 10^3 \frac{\text{gm}}{\text{gallon}}$$

$$14. \quad \frac{0.789 \text{ gm}}{\text{cc}} \times 3,785 \frac{\text{cc}}{\text{gal}} = 2.99 \times 10^3 \frac{\text{gm}}{\text{gallon}}$$



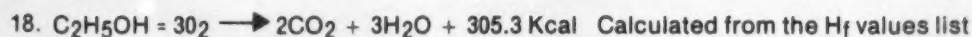
$$\frac{2.62 \times 10^3 \text{ gm}}{\text{gal}} \times \frac{1 \text{ mole C}_8\text{H}_{18}}{114.23 \text{ gm}} = 22.9 \frac{\text{moles}}{\text{gal}}$$

$$1,214 \frac{\text{Kcal}}{\text{mole}} \times 22.9 \frac{\text{moles}}{\text{gal}} = 27,800 \frac{\text{Kcal}}{\text{gal}}$$

or

$$110,400 \frac{\text{Btu}}{\text{gal}}$$

Note Conversion to Btu $3.97 \text{ Btu} = 1 \text{ Kilocalorie}$



$$2.99 \times 10^3 \frac{\text{gm}}{\text{gal}} \times \frac{1 \text{ mole C}_2\text{H}_5\text{OH}}{46.07 \text{ gm}} = 64.9 \frac{\text{moles C}_2\text{H}_5\text{OH}}{\text{gal}}$$

$$305.3 \frac{\text{Kcal}}{\text{mole}} \times 64 \frac{\text{g moles}}{\text{gal}} = 19,800 \frac{\text{Kcal}}{\text{gal}}$$

or

$$78,600 \frac{\text{Btu}}{\text{gal}}$$

Gasohol: An Energy Alternative

Sample Problem List
Page 5, Answer Sheet

**Instructor
Information . . .**

19. 107,000 Btu Gasohol
gal

$$110,400 \text{ Btu} \times 0.900 \text{ gal gas} = 9.94 \times 10^4 \text{ Btu}$$

gasoline

$$78,600 \text{ Btu} \times 0.100 \text{ gal} = \frac{7.86 \times 10^3 \text{ Btu}}{1.07 \times 10^4 \text{ Btu}}$$

ethyl alcohol gallon of gasohol

20. (a) $0.40 \times 1.00 \text{ Kg} = 0.40 \text{ Kilogram Methanol}$

(b) $\frac{170.9 \text{ Kcal}}{32.05 \text{ gm}} \times 400 \text{ gm} = 2.13 \times 10^3 \text{ Kcal}$
CH₃OH

SUPPLEMENTAL MATERIALS GUIDE

1. **ADM Gasohol News**, published by Archer Daniels Midland Company, December, 1979.
2. **Alcohol Plant Equipment Manufacturers and Suppliers**. Nebraska Gasohol Committee.
3. **American Jobs From Alcohol Fuel**. Marion Anderson and Carl Parisi, Employment Research Associates, Michigan.
4. **Corn . . . Alcohol . . . Farm Fuel! Things You Need to Know**. Iowa Corn Promotion Board and the Iowa Development Commission, Des Moines, Iowa.
5. **Directory of Nebraska Gasohol Stations**, Nebraska Gasohol Committee.
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